AN1281
APPLICATION NOTE

TS613 AS DRIVER FOR ADSL LINE INTERFACES - A SINGLE SUPPLY IMPLEMENTATION WITH PASSIVE OR ACTIVE IMPEDANCE MATCHING

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ADSL CONCEPT

Asymmetric Digital Subscriber Line (ADSL), is a new modem technology, which converts the existing twisted-pair telephone lines into access paths for multimedia and high speed data communications.

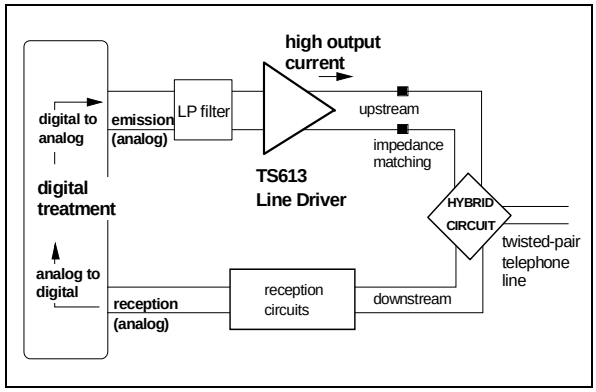
ADSL transmits more than 8 Mbps to a subscriber, and can reach 1Mbps from the subscriber to the central office. ADSL can literally transform the actual public information network by bringing movies, television, video catalogs, remote CD-ROMs, LANs, and the Internet into homes.

An ADSL modem is connected to a twisted-pair telephone line, creating three information channels: a high speed downstream channel (up to 1.1MHz) depending on the implementation of the ADSL architecture, a medium speed upstream channel (up to 130kHz) and a POTS (Plain Old Telephone Service), split off from the modem by filters.

THE LINE INTERFACE - ADSL Remote Terminal (RT):

The Figure1 shows a typical analog line interface used for ADSL. The upstream and downstream signals are separated from the telephone line by using an hybrid circuit and a line transformer. On this note, the accent will be made on the emission path.

Figure 1 : Typical ADSL Line Interface

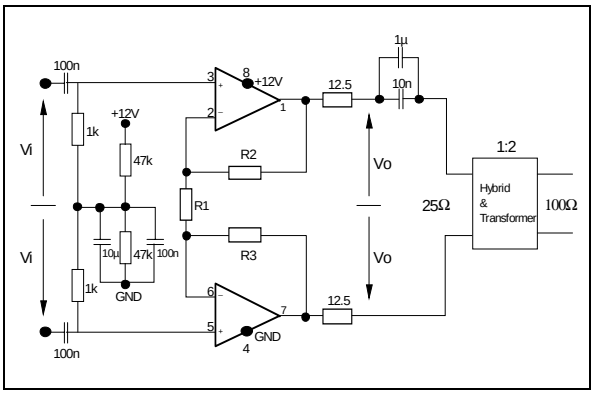


The TS613 is used as a dual line driver for the upstream signal.

For the remote terminal it is required to create an ADSL modem easy to plug in a PC. In such an application, the driver should be implemented with a +12 volts single power supply. This +12V supply is available on PCI connector of purchase.

The figure 2 shows a single +12V supply circuit that uses the TS613 as a remote terminal transmitter in differential mode.

Figure 2 : TS613 as a differential line driver with a +12V single supply



The driver is biased with a mid supply (nominaly +6V), in order to maintain the DC component of the signal at +6V. This allows the maximum dynamic range between 0 and +12 V. Several options are possible to provide this bias supply (such as a virtual ground using an operational amplifier), such as a two-resistance divider which is the cheapest solution. A high resistance value is required to limit the current consumption. On the other hand, the current must be high enough to bias the inverting input of the TS613. If we consider this bias current (5µA) as the 1% of the current through the resistance divider (500µA) to keep a stable mid supply, two 47kΩ resistances can be used.

The input provides two high pass filters with a break frequency of about 1.6kHz which is necessary to remove the DC component of the input signal. To avoid DC current flowing in the primary of the transformer, an output capacitor is used.

The 1µF capacitance provides a path for low frequencies, the 10nF capacitance provides a path for high end of the spectrum.

In differential mode the TS613 is able to deliver a typical amplitude signal of 18V peak to peak.

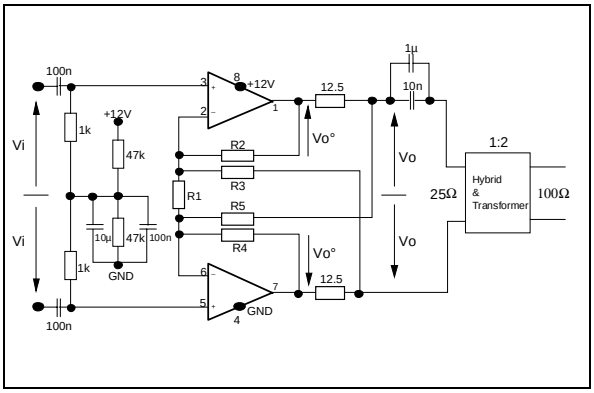
The dynamic line impedance is 100Ω. The typical value of the amplitude signal required on the line is up to 12.4V peak to peak. By using a 1:2 transformer ratio the reflected impedance back to the primary will be a quarter (25Ω) and therefore the amplitude of the signal required with this impedance will be the half (6.2 V peak to peak). Assuming the 25Ω series resistance (12.5Ω for both outputs) necessary for impedance matching, the output signal amplitude required is 12.4 V peak to peak. This value is acceptable for the TS613. In this case the load impedance is 25Ω for each driver.

For the ADSL upstream path, a lowpass filter is absolutely necessary to cutoff the higher frequencies from the DAC analog output. In this simple non-inverting amplification configuration, it will be easy to implement a Sallen-Key lowpass filter by using the TS613. For ADSL over POTS, a maximum frequency of 135kHz is reached. For ADSL over ISDN, the maximum frequency will be 276kHz.

INCREASING THE LINE LEVEL BY USING AN ACTIVE IMPEDANCE MATCHING

With passive matching, the output signal amplitude of the driver must be twice the amplitude on the load. To go beyond this limitation an active maching impedance can be used. With this technique it is possible to keep good impedance matching with an amplitude on the load higher than the half of the ouput driver amplitude. This concept is shown in figure3 for a differential line.

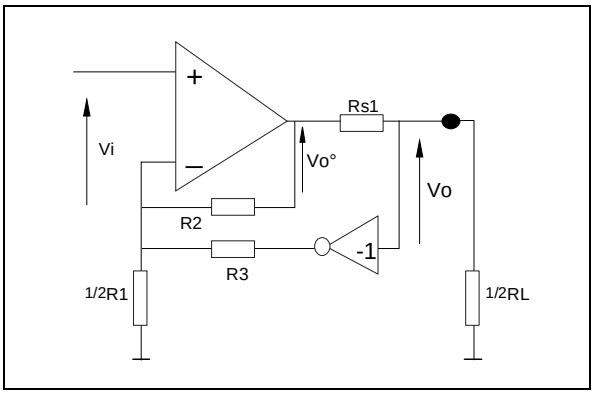
Figure 3 : TS613 as a differential line driver with an active impedance matching



Component calculation:

Let us consider the equivalent circuit for a single ended configuration, figure4.

Figure 4 : Single ended equivalent circuit



Let us consider the unloaded system. Assuming the currents through R1, R2 and R3

as respectively:

$$\frac{2Vi}{R1}, \frac{(Vi - Vo^{\circ})}{R2} and \frac{(Vi + Vo)}{R3}$$

As Vo° equals Vo without load, the gain in this case becomes :

$$G = \frac{Vo(noload)}{Vi} = \frac{1 + \frac{2R2}{R1} + \frac{R2}{R3}}{1 - \frac{R2}{R3}}$$

The gain, for the loaded system will be (1):

$$GL = \frac{Vo(withload)}{Vi} = \frac{1}{2}\frac{1 + \frac{2R2}{R1} + \frac{R2}{R3}}{1 - \frac{R2}{R3}}, (1)$$

As shown in figure5, this system is an ideal generator with a synthesized impedance as the internal impedance of the system. From this, the output voltage becomes:

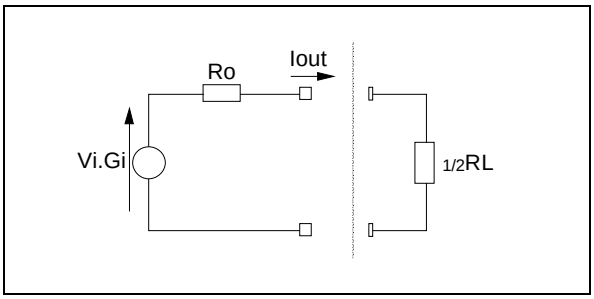
$$Vo = (ViG) - (RoIout), (2)$$

with Ro the synthesized impedance and Iout the output current. On the other hand Vo can be expressed as:

$$Vo = \frac{Vi\left(1 + \frac{2R2}{R1} + \frac{R2}{R3}\right)}{1 - \frac{R2}{R3}} - \frac{Rs1Iout}{1 - \frac{R2}{R3}}, (3)$$

By identification of both equations (2) and (3), the synthesized impedance is, with Rs1=Rs2=Rs:

Figure 5 : Equivalent schematic. Ro is the synthesized impedance



$$Ro = \frac{Rs}{1-\frac{R2}{R3}}, (4)$$

Unlike the level Vo° required for a passive impedance, Vo° will be smaller than 2Vo in our case. Let us write Vo°=kVo with k the matching factor varying between 1 and 2. Assuming that the current through R3 is negligeable, it comes the following resistance divider:

$$Ro = \frac{kVoRL}{RL + 2Rs1}$$

After choosing the k factor, Rs will equal to 1/2RL(k-1).
A good impedance matching assumes:

$$Ro = \frac{1}{2}RL, (5)$$

From (4) and (5) it becomes:

$$\frac{R2}{R3} = 1 - \frac{2Rs}{RL}, (6)$$

By fixing an arbitrary value for R2, (6) gives:

$$R3 = \frac{R2}{1-\frac{2Rs}{RL}}$$

Finally, the values of R2 and R3 allow us to extract R1 from (1), and it comes:

$$R1 = \frac{2R2}{2\left(1-\frac{R2}{R3}\right)GL - 1 - \frac{R2}{R3}}, (7)$$

with GL the required gain.

GL (gain for the loaded system)	GL is fixed for the application requirements GL=Vo/Vi=0.5(1+2R2/R1+R2/R3)/(1-R2/R3)
R1	2R2/[2(1-R2/R3)GL-1-R2/R3]
R2 (=R4)	Abritrary fixed
R3 (=R5)	R2/(1-Rs/0.5RL)
Rs	0.5RL(k-1)

CAPABILITIES

The table below shows the calculated components for different values of k. In this case R2=1000Ω and the gain=16dB. The last column displays the maximum amplitude level on the line regarding the TS613 maximum output capabilities (18Vpp diff.) and a 1:2 line transformer ratio.

Active matching					
k	R1 (Ω)	R3 (Ω)	Rs (Ω)	TS613 Output Level to get 12.4Vpp on the line (Vpp diff)	Maximum Line level (Vpp diff)
1.3	820	1500	3.9	8	27.5
1.4	490	1600	5.1	8.7	25.7
1.5	360	2200	6.2	9.3	25.3
1.6	270	2400	7.5	9.9	23.7
1.7	240	3300	9.1	10.5	22.3
Passive matching				12.4	18

MEASUREMENT OF THE POWER CONSUMPTION IN THE ADSL APPLICATION

Conditions:

Passive impedance matching
Transformer turns ratio: 2
Maximun level required on the line: 12.4Vpp
Maximum output level of the driver: 12.4Vpp
Crest factor: 5.3 (Vp/Vrms)

The TS613 power consumption during emission on 900 and 4550 meter twisted pair telephone lines: **360mW**

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